# Processing Characteristics and Oxidative Stability of Soybean Oil Extracted with Supercritical Carbon Dioxide at 50 C and 8,000 psi[1]

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## ABSTRACT

The crude oil extracted from soy flakes with supercritical carbon dioxide ($SCCO_2$) was characterized for color, free fatty acid, phosphorus, neutral oil loss, unsaponifiable matter, tocopherol and iron content and compared to a commercial hexane-extracted sample of crude degummed oil. Characterization and processing studies indicate that $SCCO_2$ extraction yields a product comparable to a hexane-extracted degummed oil. However, hexane-extracted degummed soybean oils exhibit better oxidative stability because phosphatides, which are natural antioxidants, are essentially absent in $SCCO_2$-extracted oils.

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## INTRODUCTION

Previous reports from this laboratory have shown that extraction of soy flakes with $SCCO_2$ at 50 C and 8,000 psi yields crude oil similar to degummed hexane-extracted oil (1,2). This report presents some properties and processing data for soybean oils obtained by $SCCO_2$ extraction under the aforementioned conditions.

## EXPERIMENTAL

The $SCCO_2$ extraction methodology has been described previously (1,2). Soybeans were Tiger Brand certified seeds. AOCS Official Methods were used for the analyses (3). Processing (4) and oil evaluation methods (5) were described

TABLE I

**Processing[a] and Properties of $SCCO_2$- and Hexane-Extracted Crude and Finished Soybean Oils**

| Crude oils | FFA % | Lovibond Color Y | Lovibond (5¼") R | Phosphorus ppm | Neutral oil Loss % | Iron, ppm | Unsaponifiables % | Tocopherols µg/g |
|---|---|---|---|---|---|---|---|---|
| $SCCO_2$-50 C 8,000 psi | 0.30 | 70 | 8 | 1 | 0.6 | 0.3 | 0.66 | 1620 |
| Hexane degummed | 0.28 | 70 | 10 | 153 | 1.1 | 0.7 | 0.64 | 1020 |

| Finished oils | Refining % excess 10% Lye | Color-Lovibond (5¼") Refined Y | Refined R | Bleached Y | Bleached R | Deodorized Y | Deodorized R | Flavor scores and significance[b] 0 Time | 4 days 60 C |
|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 0.2 | 70 | 6 | 35 | 3.5 | 10 | 0.3 | 7.4 } + | 5.9 } + |
| $CO_2$ | 0.5 | 70 | 6 | 35 | 4.0 | 10 | 0.3 | 7.1 | 5.8 |
| $CO_2$ | 0.05 | 35 | 7 | 35 | 3.5 | 6 | 0.3 | 7.1 } + | 6.3 } + |
| $CO_2$ | 0.10 | 35 | 7 | 35 | 3.5 | 8 | 0.3 | 7.4 | 6.3 |
| Hexane | 0.05 | 40 | 9 | 40 | 4.5 | 8 | 0.2 | 8.0 } + | 7.1 } + |
| Hexane | 0.10 | 40 | 8 | 40 | 3.5 | 8 | 0.2 | 8.4 | 7.4 |

[a]Refining at 60 C, 5 min contact time, bleaching ½% activated clay 105 C, 15 min vacuum, deodorization 3 hr, 210 C, 1 mm Hg.

[b]+ denotes no statistical significance, oils contained .01% citric acid added on the cooling side of deodorization.

previously. Tocopherol was determined according to AOAC Method 43-092 (6). The crude, crude-degummed and lecithin samples were obtained from commercial sources. Oxidative stability of crude oils was determined according to Olcott and Einset (7).

## RESULTS AND DISCUSSION

Processing and compositional data for $SCCO_2$- and hexane-extracted oils are given in Table I. The free fatty acid and unsaponifiable matter for $SCCO_2$- and hexane-extracted crude oil are nearly identical. Although the color of $SCCO_2$-extracted oil was about 2 red units lighter than the hexane-extracted oil, color removal at later stages of processing was virtually identical for both oil types. As reported previously, phosphatides show little solubility in $SCCO_2$ and therefore the product contains more neutral oil than a hexane-extracted crude degummed oil. Unpublished work has indicated that undefined parameters in the $SCCO_2$ process affect the tocopherol content of crude oils. Thus, the tocopherol content of the $SCCO_2$ extracted oil was somewhat higher than the hexane-extracted oil.

Portions of $SCCO_2$- and hexane-extracted oils were refined with 10% NaOH in excesses ranging from .05-0.5%. Color measurements taken after refining, bleaching and deodorization showed that the amount of excess refining lye has little effect on color removal.

Flavor evaluations showed that oils of good initial quality were obtained with flavor scores of 7-8 on a 10-point scale (10 = bland, 1 = extreme). Flavor scores after 4 days storage at 60 C indicated that normal deterioration had occurred during accelerated storage. That no significant differences were found between the initial or aged flavor scores of any of the oils suggests that the lye requirements for refining a $SCCO_2$-extracted crude oil are only slightly more than theoretical and less than required to refine conventionally extracted oils. Both hexane- and $SCCO_2$-extracted oils refined well with 10% NaOH at excesses of .05-.1%. These results indicate that $SCCO_2$ extraction yields a crude oil having properties very much like those of oil obtained by hexane extraction and degumming.

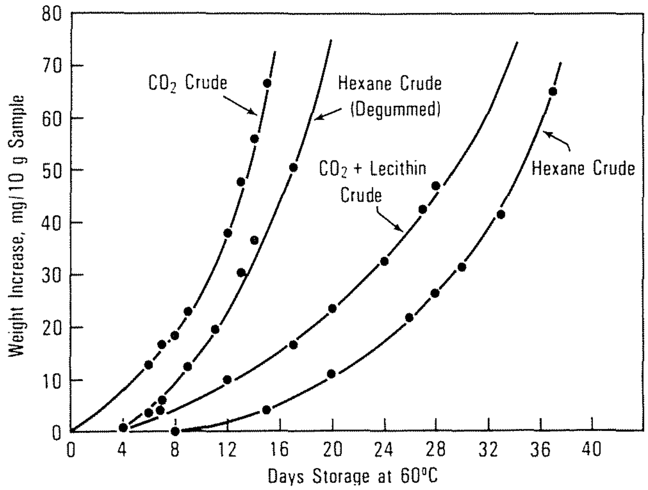


**FIG. 1. Oxidative stability of $SCCO_2$- and hexane-extracted crude oils under Schall oven storage conditions: 10-g sample in 100-ml beaker. $SCCO_2$ crude + lecithin contained 2% commercial fluid unbleached lecithin.**

Published work has shown that the oxidative stability of soybean oil decreases with processing. Crude oil is the most stable, followed by degummed oil, with refined and bleached oil the least stable (8). The relative oxidative stability of $SCCO_2$ and hexane crude oils are shown in Figure 1. Despite the rather high levels of tocopherol found in $SCCO_2$-extracted oil, it is markedly less stable than a hexane-extracted crude oil. The role of phosphatides in protecting crude oils from oxidation is not entirely clear, and it is not known whether they act as true antioxidants, as metal inactivators, or as synergists in conjunction with naturally occurring tocopherols. Nonetheless, results in Figure 1 show that degumming of hexane-extracted crude oil lowers oxidative stability and that addition of soy phosphatides to $SCCO_2$-extracted crude oil markedly improves oxidative stability. Although further work is required to elucidate the mechanism by which phosphatides protect crude oils, they may act as oxygen barrier at the oil/air interface and thus reduce the rate of oxygen uptake by the sample. However, it should be pointed out that a high level of tocopherol in the absence of phosphatides is not sufficient to protect crude $SCCO_2$-extracted oils and that they should not be stored for extended periods.

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